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At 10–12 Months, Pointing Gesture Handedness Predicts the Size of Receptive Vocabularies

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The close association between language and gesture has been widely studied (McNeill, Psychological Review, 92, 1985, 350). It remains unclear, however, when and how this relationship originates ontogenetically. This study investigated the relationship between vocabulary development and pointing handedness in 10- to 12-month-old infants. The study used cross-sectional data from 16 infants. Infants took part in a pointing elicitation task and a grasping task to assess their pointing and grasping handedness. Further, parents filled out the Oxford Communicative Development Inventory (Hamilton, Plunkett, & Schafer, Journal of Child Language, 27, 2000, 689) to assess infants' receptive and productive vocabularies. The result showed a positive, significant correlation between receptive vocabulary development and right-handed pointing. This relationship was not due to age or to vocalizations, which have not been ruled out by previous studies. Possible mechanisms behind this codevelopment are discussed.

Referring to objects and events is a key corner stone of human communication. This ability emerges toward the end of the first year of infants' life. Infants start to produce

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their first word around 10–14 months (Iverson & Goldin-Meadow, 2005), and their first pointing gestures at around 11 months (Bates, 1976; Butterworth & Morissette, 1996). This study investigated the relationship between pointing gestures and vocabulary development in 10- to 12-month-old infants.

It is well known that the brain is organized such that different neural areas are specialized in different processes and that processes may be more dominant in the left or right hemisphere. One of the most well-known examples of this type of laterality that the left hemisphere is typically dominant in language processing (e.g., adults: Knecht et al., 2000; Kimura, 1973a, 1973b; infants: Dehaene-Lambertz, Dehaene, & Hertz-Pannier, 2002; Holowka & Petitto, 2002). As well as neuroimaging techniques, left dominance for language processing can be inferred from observable behaviors including a right or left ear advantage (Kimura, 1973a, 1973b) and mouth asymmetries during speech production (Argyriou, Byfield, & Kita, 2015; Graves, Goodglass, & Landis, 1982). Neuroimaging studies have also revealed that gesture processing may also be left-lateralized both in terms of comprehension (Decety et al., 1997) and production (Moll et al., 2000). For example, the left hemisphere including the inferior frontal gyrus (Broca's area) and middle temporal gyrus, become more active when the person is watching meaningful hand actions as compared to meaningless actions (Decety et al., 1997). Finally, as body movements are processed in the contra-lateral hemisphere (Cincotta & Ziemann, 2008), lateralization for the production of body movements including gestures may be inferred by the side of the body the movement is spontaneously executed on. This is consistent with work on split-brain patients, who have had their corpus callosum severed. These patients demonstrate different types of information encoded in their left and right-handed gestures in line with the hemispheric dominance for language in the left hemisphere and emotion in the right hemisphere (Lausberg, Zaidel, Cruz, & Ptito, 2007).

Although language and gesture are typically processed by the left hemisphere, as reviewed above, there are exceptions to this general tendency. In such exceptional cases, the hemispheric dominance for language processing is associated with spontaneous hand choice for speech-accompanying gestures in adults. This was demonstrated by Kimura's (1973b) study that took advantage of individual differences in language laterality among left-handers. Left-handers whose language was left dominant produced more right-handed gestures than those whose language was bilaterally distributed. Another demonstration took advantage of the fact that processing of metaphor involves right hemisphere strongly even for speakers who normally process language in the left hemisphere (e.g., Mashal, Faust, Hendler, & Jung-Beeman, 2007; Winner & Gardner, 1977). The right-hand preference for gesturing (in right-handed participants) was weaker when talking about metaphorical contents than nonmetaphorical contents (Kita, de Condappa, & Mohr, 2007). That is, metaphor processing activated the right hemisphere, which in turn generated more left-handed gestures, weakening the default right-hand preference in gesturing. To summarize, the systematic relationship between-hand choice for gesturing and language lateralization indicates that gesture and language share underlying processes in one of the hemispheres and they arise from an integrated system.

The idea that gesture and language are processed by one unified communicative system (McNeill, 1985) has drawn much attention in the recent literature. This may be because of the wide implications of such a system, including evidence for a gestural origin of language in evolution (e.g., Corballis, 2003) and for embodied nature of language processing (e.g., Glenberg & Gallese, 2012). An integrated system can also explain developmental patterns and to develop theories of language development (e.g., Iverson & Goldin-Meadow, 2005). For example, the onset of a certain type of word-pointing–gesture combination in the one-word stage of language development predicts the onset of word–word combinations a few months later (Iverson & Goldin-Meadow, 2005). Neuroimaging evidence also supports the idea of speech and gesture as a unified system (e.g., Xu, Gannon, Emmorey, Smith, & Braun, 2009). Although language and gesture in adults may share a common neural and/or processing basis, it remains unclear how this relationship originates ontogenetically. One importance source of information in the discussion of this ontogenetic relationship is which hands infants spontaneously choose to produce gestures.

The hand choice for gesturing seems to be related to language development. Infants and children (e.g., Cochet, Jover, & Vauclair, 2011; Esseily, Jacquet, & Fagard, 2011; Locke, Bekken, McMinn-Larson, & Wein, 1995; Vauclair & Imbault, 2009) as well as nonhuman primates (Meguerditchian & Vauclair, 2009) produce gestures with the right hand more often than with the left hand, suggesting that the left hemisphere is dominant for gesture production. Moreover, for children, right-handed lateralization patterns are particularly clear during key points in language development. For example, Locke et al. (1995) found a relationship between the onset of babbling and right-handed, repetitive shaking actions made on an object in 18- to 28-week-old infants. With regard to gestures made without objects, Cochet et al. (2011) found that children became more right-handed for pointing around the time of their lexical spurt (14–20 months). Furthermore, 14- to 16-month-olds with a right-hand bias for pointing had larger vocabularies than infants without such a bias (Esseily et al., 2011). However, the study by Esseily and colleagues did not consider age and vocalization in the analysis. Therefore, the relationship between right-handed pointing and vocabularies may have simply been due to general maturational factors (independently related to pointing and language). It could also be due to temporary activation of the left hemisphere during vocalizations, which may be more frequent in infants with larger vocabularies. When infants produce speech-like vocalizations, they may activate the left hemisphere and this activation may heighten the activation of the left-hemisphere motor control system in general and increase the frequency of right-hand gestures. Such an interpretation is plausible, given the finding that chimpanzees are more likely to use their right hand to gesture if they are vocalizing (Hopkins & Cantero, 2003).

CURRENT STUDY

The current study investigated whether, in 10- to 12-month-old infants, vocabulary development and a right-hand bias in pointing are associated in the way suggestive of codevelopment of language and gesture in the left hemisphere. More specifically, we examined how frequency and right-hand bias in pointing gestures are related to vocabulary size. The design of the study allowed us to rule out temporally activation of the left hemisphere due to vocalization or general age-related maturation as the explanation for these associations.

We investigated 10- to 12-month-old infants, who are at the very onset of referential communication, because they have very limited experience of producing pointing gestures, especially, of meaningfully combining speech and gesture (Bates, 1976; Iverson & Goldin-Meadow, 2005). We elicited pointing and grasping from infants with similar procedures. The experimenter showed an interesting toy at her torso midline out of the reach of infants and held the toy there in the pointing task or placed the toy on the table within infants' reach in the grasping task. We recorded the hand choice for pointing and grasping, and the frequency of pointing (in the grasping task, children grasped the toy in virtually all trials). Then, we correlated these variables with the size of the infants' receptive and expressive vocabularies, as assessed by Oxford Communicative Development Inventory (CDI) (Hamilton et al., 2000). We predicted that a larger vocabulary would be associated with more right-handed pointing, but not with the proportion of right-handed object manipulation.

METHOD

Participants

Twenty-eight 10- to 12-month-old infants took part in the study (15 females and 13 males, M = 335.5 days, SD = 27.9). We excluded one infant whose receptive vocabulary was implausibly high and over 2.5 SD above the whole group's mean (M = 11.1, SD = 9.41, *individual's score* = 38.0).

Participants were recruited through a university database. Families were reimbursed £10 in travel expenses and received a toy in return for participation. Although when parents were first contacted about the study, they were informed that it was investigating pointing gestures, they were not asked explicitly whether or not their infant used points to communicate.

We excluded five participants who produced no pointing gestures and six participants who only produced one pointing gesture each. The participants with no pointing gestures, pointing handedness cannot be calculated. The participants with only one pointing gestures was excluded because their handedness score would always take an extreme value of +1 or −1 and thus add noise to the analysis (see Supporting Information for analysis that include these participants). Thus, 16 participants were analyzed (10 females and six males; M = 337.6 days, SD = 26.8).

Of these 16 infants, 12 were described by their parents as being White-British, one was described as White-Other, and three were mixed ethnicity. Fourteen were English monolingual, and two were also acquiring German. Eight children did not have siblings, seven had one older sibling, and one was the youngest of four siblings. Four children had had at least one ear infection. Nine children had at least one parent who is educated to at least Bachelor's degree level, five had at least one parent who is educated to some college/university level, and two had at least one parent who is educated to high school level. The fathers of all children were in full-time employment. Five of the mothers were currently on leave from work, or stay at home parents, eight were employed part time and three were self-employed.

Stimuli

The study used the Oxford CDI (Hamilton et al., 2000) to obtain an index of infants' productive and receptive vocabulary development.[1] This is a check list of 416 words,

[1]It should be noted that the use of a single-language measure may be inappropriate for children acquiring more than one language as it may not accurately represent their entire vocabulary.

which parents tick if they believe their child understands, or understands and says. Scores for productive and receptive vocabulary can then be worked out as a percentage of the total number of items on the list.

This study used 20 small, attractive toys (e.g., colored cars) to elicit gestures and grasping actions (one toy per trial). The toys were roughly symmetrical, so as not to bias hand choice. The order of toys and whether the toys were used in grasping or pointing trials was counterbalanced.

Procedure

Testing occurred in a small room, in a baby laboratory at the University of Birmingham. Although the infants had chance to interact with the experimenter before the experiment took place, there was no official or structured warm-up period.

All participants took part in both the grasping and the pointing task. The order of tasks was counterbalanced across participants. There were 10 trials per task (20 trials in total). Infants carried out the two tasks one after the other without any break in between. For both tasks, the infants sat on their mother's lap. Mothers were instructed not to talk to their infant or to try to guide their attention. See Figure 1 for the setup in both tasks. The experimenter always handled the toys bimanually, so as not to bias hand choice in the current and subsequent trials.

For both tasks, at the start of trials the experimenter held up a toy, shook it and said "Look at this!" For the pointing task, the toy was then put on the table in front of the experimenter (approximately 120 cm from the infant). For grasping trials, the toy was placed in easy reach of the infant (approximately 10 cm from the infant). The experimenter then waited for 15 sec. In pointing trials, if the infant pointed (or tried to reach for the toy), the toy was given to them. If they did not point or reach during these 15 sec, the experimenter repeated the process (saying: "Look at this! Isn't it pretty!?"). If they did not point or reach after the second set of 15 sec, the toy was given to them. Grasping trials followed the same procedure, except that the target action was grasping of the toy rather than pointing (or reaching) toward the toy.

In addition to these tasks, mothers were asked to complete the Oxford CDI.

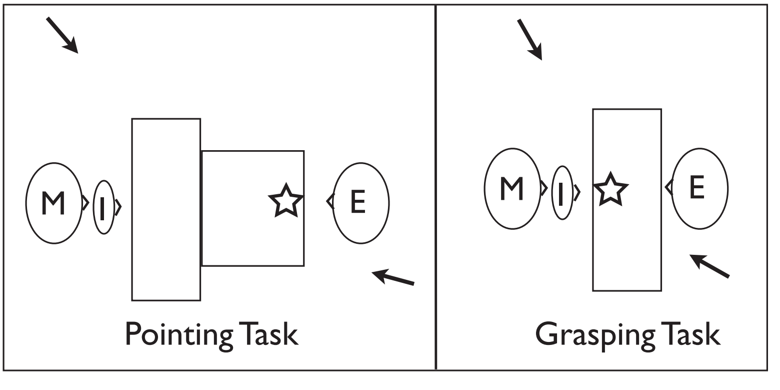

Figure 1 The setup for both tasks (not drawn to scale). "M" indicates the mother, "I" indicates the infant, and "E" indicates the experimenter. The rectangles depict tables and the star depicts the location of the toy. The arrows represent the location and direction of the cameras.

Coding

Two video recorders were used, one facing and one from the side of the infant. These videos were synchronized and coded using the video annotation software ELAN (European Distributed Corpora Project [EUDICO] Linguistic Annotator, developed by the Max Planck Institute for Psycholinguistics).

All gesture information came from pointing trials, and all grasping information came from grasping trials. In pointing trials, gestures were coded from the moment that the toy became visible to the infant, until the end of either a failed reach or a point, or the end of the trial if children did not reach or point. In grasping trials, only grasping was coded.

Gestures were coded into one of five gesture types (points, failed reach, banging the table, waving, other) but as this article focuses on points only these will be discussed. Points were defined as the infant extending one or both of their arms toward the toy or upwards, without leaning forward. This is in contrast to failed reaches, where the infant extended their arm/s and also leaned toward the toy. Thus, whether or not an infant leaned, was the distinguishing feature between pointing and failed reaching. Although there is no precedence in the literature for using this distinction, it was clear that when the infants were leaning they were attempting to grab the toy themselves rather than point to it to influence the behavior of the adult. Gestures directed at other objects were not coded. Grasping of a toy was coded for infants' initial touch (e.g., lifting, rolling, or stroking the toy).

Each action was coded for hand choice: left, right, and bimanual. Grasps were coded as bimanual if both hands made contact with the toy within five frames of each other. Gestures were coded as bimanual whenever both hands were used, regardless of the size or duration. Bimanual actions were further coded by dominance as left, right, or equal. For gestures, dominance was determined by the leading hand or the hand that made the bigger gesture. In cases where one hand started the gesture but the other was larger, or if dominance appeared to change hands over the gesture, then they were coded as equal. For grasps, the dominant hand was the one that appeared to be most in control of the toy.

We obtained high intercoder reliability for the coding. See Appendix S1 for more details.

Speech-like vocalizations were coded during pointing trials, from when the toy became visible to the infant to when the infant made a failed reach or pointing gesture (or until the end of the trial if the infant did not point or reach). They were coded using a binary system (speech-like vocalization or no speech-like vocalization) and included babbling, speech-like vocalization with emotional tone (as if the infant was complaining or protesting), and humming but not coughing, crying, or laughing. A binary system was used as all speech-like vocalizations were considered to be communicative, regardless of their linguistic content, as they are all likely to be controlled by the left hemisphere. Research has found that voluntarily controlled vocalizations of chimpanzees, which do not have language in the same sense as humans, are left-lateralized (Reynolds Losin, Russell, Freeman, Meguerditchian, & Hopkins, 2008; Wallez et al., 2012).

Hand shapes of points were also coded for, as research has shown that different pointing functions are associated with different forms. Specifically, infants are more likely to use an open hand/spread shape for imperative points and an index finger shape for declarative points (Cochet & Vauclair, 2010). Points were coded as one of six hand shapes: *index finger* (prototypical pointing shape), *index separate* (index extended and other fingers curled but not tightly), *spread* (all fingers extended), *relaxed* (hand appears relaxed with no clear fingers extended or tightly curled), *fist* (all fingers curled into a fist), and *other* (arrangement of fingers did not fit any of the other categories).

Analysis

The receptive and productive vocabulary variables were measured using the Oxford CDI (a parental questionnaire). The scores represent the percentage of words on the list that parents reported that their infant understood or spoken. A large CDI score therefore reflects more words understood or produced. The study also measured the number of points produced in the pointing trials (range: 2–10), age (in days) and the proportion on time spent vocalizing within pointing trials.

Finally, the study measured handedness for grasping and pointing for each infant. Handedness scores were calculated using the following formula:

$$\text{Handedness} = \frac{R - L}{R + L + B_{\text{equal}}}$$

R, the number of unimanual right-handed action + the number of right dominant bimanual action. L, the number of unimanual left-handed action + the number of left dominant bimanual action. B_{equal}, the number of bimanual action with no clear dominant hand.

Thus, a score of 1 reflects a pure right-hand bias and a score of -1 reflects a pure left-hand bias. A score of 0 reflects an absence of a bias.

Spearman's (nonparametric) correlations were used throughout so that normal distribution did not have to be assumed, and we could eliminate false-positive results due to outliers. We did not adjust p-values for multiple comparisons as we tested only correlations that are theoretical motivated.

RESULTS

Descriptive statistics

Of the 16 infants included in the main analysis, two pointing trials (both from the same participant) were excluded due to infant fussiness. Furthermore, six grasping trials were excluded. Four of these were from one participant (for two trials, toys were given without the verbal phrase "Look at this"; for another trial, a toy was placed at the wrong orientation by the experimenter and in another trial the infant did not pick up the toy), in one trial from a different infant the toy was put on the infant's hand accidently, and in one trial from another infant the infant did not pick up the toy. Two additional trials (one trial from two infants) were also excluded: for one trial, a child was not sat centrally and for the other, the toy was placed on the infant's hand by the experimenter. Therefore, the final count for handling trials was 154 (16 participants $\times$ 10 trials $-$ 6 exclusions in three participants).

The final analysis included 89 points, made up from 48 unimanual points and 41 bimanual points (of which 31 were coded as having a dominant hand), and 154 grasping actions, made up from 97 unimanual grasps and 57 bimanual grasps (of which 21 were coded as having a dominant hand). The scores were as follows: pointing handedness, $M = 0.190$, $SD = 0.572$; grasping handedness, $M = 0.157$, $SD = 0.425$; receptive vocabulary, $M = 10.1$, $SD = 8.34$; productive vocabulary $M = 0.736$, $SD = 0.782$. Further, on average infants produced 5.56 ($SD = 2.58$) points over the ten pointing trials (range: 2–10). The mean proportion of the time in pointing trials spent vocalizing was .0607 ($SD = 0.0454$).

A t-test found that there was no significant difference between grasping and pointing handedness scores. Further, as a group, neither infants' grasping handedness nor their pointing handedness was significantly different from 0, showing that they did not have any global handedness bias.

Of the 130 hand shapes that made up the 89 points (48 unimanual + 2* 41 bimanual), 39 were coded as index separate, 28 were coded as spread, 26 were coded as index finger, 22 were coded as relaxed, 8 were coded as fist, and 7 were coded as other. Due to the small number of data points in each category, this data was not analyzed further.

Correlational analysis

Relationship between vocabulary and pointing handedness

First, the relationship between productive/receptive vocabulary and pointing handedness was investigated (Table 1). There was a significant positive correlation between pointing handedness and receptive vocabulary scores (with a large effect size, Cohen, 1992; see Figure 2). That is, infants who had a large receptive vocabulary also showed a larger right-hand bias for pointing. There was no relationship between pointing handedness and expressive vocabulary ($p > .1$).

Importantly, neither receptive vocabulary scores nor pointing handedness correlated with age or the proportion of time spent vocalizing ($p > .1$ for both). Further, partial correlations between receptive vocabulary and pointing handedness remained significant after controlling for either age (R (13) = .533, $p = .041$) or the proportion of time spent vocalizing (R (13) = .530, $p = .042$).

Finally, when considering all children, the frequency of pointing gestures (proportion of trials in which a pointing gesture was produced) did not significantly correlate with receptive or expressive vocabulary ($p > .1$ for both; see Supporting information for more details).

TABLE 1
Spearman's R for the Nonparametric Correlation Between Vocabulary Measures from CDI, and Handedness of Manual Behaviors (Pointing and Grasping)

	Pointing handedness (N = 16)	*Grasping handedness (N = 16)*
Receptive vocabulary	.506* (see Figure 2)	−.192
Expressive vocabulary	−.391	−.155

*. $p < .05$.

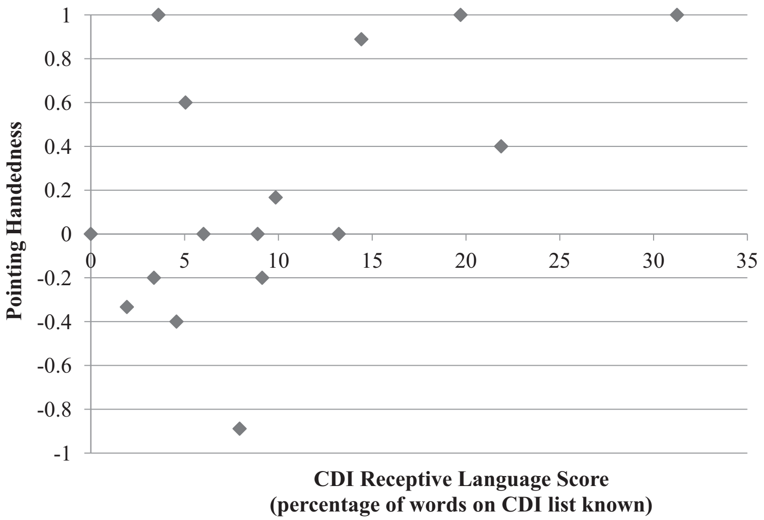

Figure 2 Scatter plot of infants' receptive vocabulary size (CDI receptive scores) and pointing handedness (−1 reflects a pure left-hand bias, 1 reflects a pure right-hand bias, 0 reflects an absence of a bias). Spearman's $R = .506$ ($p < .05$).

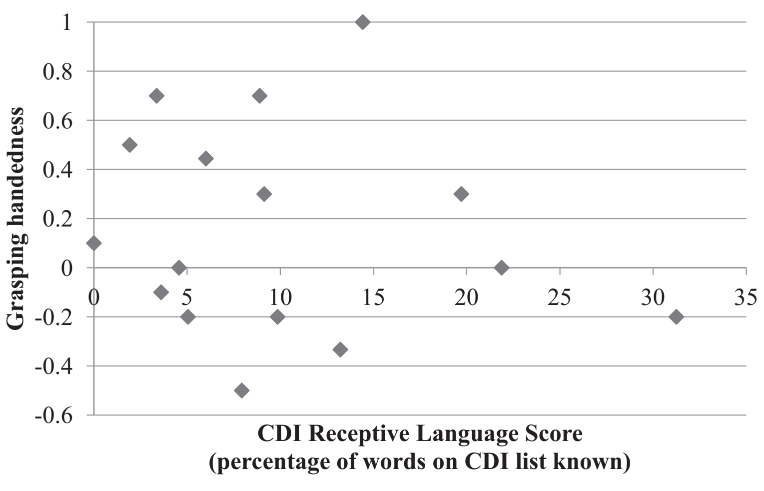

Figure 3 Scatter plot of infants' receptive vocabulary size (CDI receptive scores) and grasping handedness (−1 reflects a pure left-hand bias, 1 reflects a pure right-hand bias, 0 reflects an absence of a bias) ($p > .1$).

Relationship between vocabulary and grasping handedness

For the same 16 participants as in the analysis of gesture handedness, grasping handedness did not significantly correlate with the receptive or expressive vocabulary size (Spearman correlation, $p > .1$ for both). See Figure 3 for the data for receptive vocabulary and grasping handedness. Finally, the handedness for grasping did not significantly correlate with the handedness of pointing ($p > .1$).

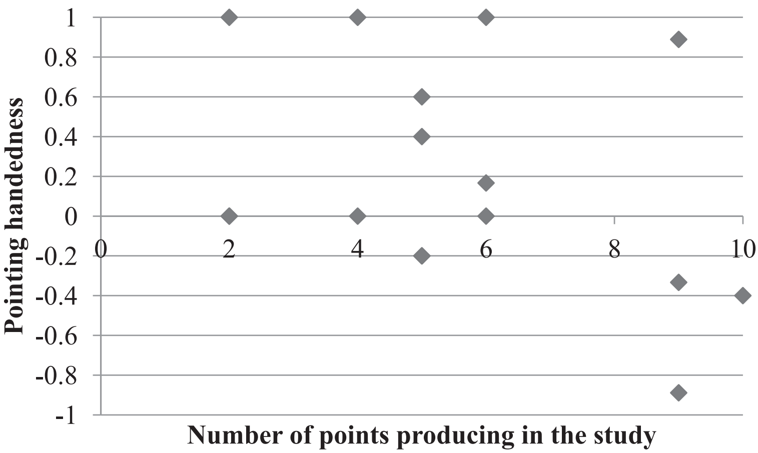

Figure 4 Scatter plot of the number of points that infants produced during the study and their pointing handedness (-1 reflects a pure left-hand bias, 1 reflects a pure right-hand bias, 0 reflects an absence of a bias) ($p > .1$).

Relationship between pointing handedness and frequency of pointing gestures

For the same 16 participants, pointing handedness and frequency of pointing gestures were not significantly correlated (Spearman correlation $p > .1$; See Figure 4).

DISCUSSION

The present study investigated the relationship between hand dominance in pointing gesture and vocabulary development in 10- to 12-month-olds, who are at the very onset of referential communication (pointing and first words). We found that infants' receptive vocabulary was positively correlated with their pointing handedness, such that the larger the receptive vocabulary was, the more right-handed their pointing was. Furthermore, handedness for objective manipulation was not correlated with receptive vocabulary. Thus, toward the end of the first year of life, the linguistic ability becomes strongly associated with handedness of pointing in a specific way, but not with the handedness object manipulation. The pattern of association is suggestive of the idea that the left hemisphere starts to control both language and pointing (cf. Kimura, 1973a, 1973b), and more generally, underlying representations for language and gesture starts to be generated by a single process (McNeill, 1992). Importantly, this relationship was not mediated by age or the amount of time spent vocalizing, ruling out general maturation and the temporary activation in the left hemisphere as explanations.

It is important to note that the use of pointing gestures by an infant may influence a parent's perceptions of their infant's receptive vocabulary (e.g., they can respond to questions using points). This could alter how parents complete the Oxford CDI and inflate vocabulary scores in a way which may not accurately represent their infant's lexical knowledge. However, this is unlikely to have driven the observed pattern, as the dependant variable was gesture handedness, rather than use of gestures. It is unlikely that parents will perceive their infant as understanding more words if they use their right hand to point as compared to their left.

The current study furthers the literature by demonstrating the association between handedness of pointing and language at an earlier age than previous studies (e.g., Cochet et al., 2011; Esseily et al., 2011). Infants at this age are at very limited experience of producing gesture and speech simultaneously in a meaningful sense (Iverson & Goldin-Meadow, 2005).Thus, the association is unlikely to be a result of producing word–gesture combinations. Possible speculations as to how the association arose will be discussed in the next section.

Some caveats are in order regarding lack of significant correlation for grasping handedness, expressive vocabulary, and gesture frequency. Null results are always difficult to interpret, but may be especially so in the current study because of the small sample size, language-related heterogeneity in the sample (e.g., two bilingual children), and a narrow range of values in the expressive vocabulary size.

How might receptive language abilities and gesture handedness become associated through social interactions?

We suggest two possibilities, which both arise from caregiver–infant interactions, but differ in the directionality of the effect. At this time, these are both speculation and are not mutual exclusive of each other, such that they may both coexist. It is an important future research topic to tease apart these possibilities.

The first possibility is that language comprehension processes in the left hemisphere pulls the gesture production system into the same hemisphere. Caregivers may ask their infants questions (e.g., "Where's the doggie?"), and infants may respond by pointing at the referent (e.g., DeLoache & Demendoza, 1987). Speech perception may activate the left hemisphere (Dehaene-Lambertz et al., 2002), biasing infants to point with their right hand. Having a larger receptive vocabulary will enable infants to experience more of this type of interaction, which makes it more likely that the left hemisphere becomes the default hemisphere to produce points (even when they are not answering a verbal question).

The second possibility is that right-handed pointing facilitates the growth of receptive vocabulary. As most adults have left-lateralized language, they demonstrate a right-hand bias in gesturing (Kimura, 1973a). It is possible that some infants have a stronger tendency to imitate this right-hand bias than others. When infants point, caregivers are likely to respond verbally (e.g., "That's a doggie" after infant points to a dog) (Kishimoto, Shizawa, Yasuda, Hinobayashi, & Minami, 2007). If infants use their right hand to point, this may activate the left hemisphere, which may in turn help the infants to learn a new word in the caregiver's utterance.

Support for this bottom-up priming accounts comes from research showing that when adults tap their fingers they perform better in a word retrieval task than when they do not move their fingers, presumably due to the cortical overlap between motor and speech production areas (Ravizza, 2003). However, further neuroscientific research is needed to establish how plausible these explanations may be.

Why was only receptive vocabulary, and not productive vocabulary associated, with right-handed pointing?

The current study did not find a relationship between productive vocabulary and gesture handedness, although such an association was found in older infants (e.g., Esseily et al., 2011). One possible account for this difference is that 10- to 12-month-olds' productive vocabulary may be limited by other factors that are not related to lateralization. For example, it may be that at this very young age, productive vocabulary is mediated by the ability to control the vocal apparata. Infants in previous studies, which showed a relationship between productive vocabulary and right-handed pointing, were older and may have not been limited by motor control of vocal apparata.

As infants' motor control increases, their productive vocabulary can develop at a faster rate and can become associated with right-handed pointing, possibly through social interactions as described above. For example, when a caregiver asks "where's the doggie?" the infant can point and imitate the word. The speech production will increase activation in the left hemisphere, such that the point is more likely to be right-handed. Further, if a child points to a referent, and a caregiver labels it, the infant can imitate the label. If the infant used the right hand, this may have pre-activated the left hemisphere such that the imitation of the word is more likely to be remembered and may enter into the child's productive vocabulary. Further, as infants age, they are more able to produce meaningful referential speech–gesture combinations. The activation of the left hemisphere caused by the speech may make the right hand more likely to be selected. Therefore, as infants become more able to articulate words, this can strengthen the association between language development and right-handed pointing in the left hemisphere. Again, these are speculative accounts at the moment and further research should investigate these ideas directly.

Are language development and right-handed pointing associated at the motor planning stage?

In contrast to previous studies, the current study found that receptive vocabulary but not productive vocabulary was associated with right-handed gesturing. Most previous studies which have found a link between language and gesture have focused on language production, such as babbling (Locke et al., 1995) and the lexical spurt (Cochet et al., 2011). This association may be the result of the left hemisphere's advantage in planning motor actions, and not a direct association between gesture and language. The current study, however, found that receptive, rather than productive, vocabulary relates to right-handed pointing development.[2] Further, similar to previous studies (e.g., Cochet & Vauclair, 2010; Esseily et al., 2011), the current study found no association between grasping and pointing handedness, and also no relationship between vocabulary development and grasping handedness. The current study therefore shows that the relationship between vocabulary development and right-handed pointing is deeper than an association at the motor planning stage. Communicative hand gestures, but not manual hand actions, do seem to be tied to the language system reinforcing the idea that the two develop together.

Did more socially interactive infants have more developed language?

The results found no associations between the number of pointing gestures infants produce and vocabulary size or pointing handedness. Similarly, there was no association between the amount of time an infant spent vocalizing and vocabulary. Thus, it was

[2]Although Esseily et al. (2011) found a relationship between language comprehension and pointing handedness as they failed to account for age and vocalisations, the nature of the relationship is not clear.

not the case that the infants who were more socially interactive had more developed language. This is interesting as it may be expected that children who are more motivated to communicate would do so in both gesture and language. The reason for this finding is not clear. However, it may be the actual raw number of points is not critical, but rather and how the points are used. For example, the study by Iverson and Goldin-Meadow (2005) speech–gesture combinations only predicted the two-word stage when the two modalities added separate information. Thus, the use of a point in itself did not predict language development. In the current study, there may not have been enough opportunities to demonstrate varied use of points in order to understand whether pointing use in itself is related to gesture lateralization or vocabulary development.

Topics for future studies

First, future studies can distinguish imperative and declarative pointing and investigate their respective relationships with the vocabulary size. Second, future studies can have finer-grained categories for speech-like vocalizations (e.g., babbling vs. nonbabbling) to see if they have differential impact on correlations between measures related to pointing gestures and the vocabulary size. Third, future studies should measure cerebral lateralization of language processing and pointing production, using neurophysiological methods, to substantiate the current study's speculations regarding neural mechanisms.

Implications

The observed relationship may have important practical implications. As infants around this age produce limited spoken language, monitoring their language development is difficult. Although far more research is needed, the current study suggests that gesture handedness could potentially be used as an indicator for language development. Although gesture handedness is unlikely to be useful enough to assess language development on its own, without additional information, it may be a useful measure especially when assessing bilingual children or children whose language has not been well studied and so norms have not been obtained.

GENERAL CONCLUSION

The current study provides evidence that vocabulary and gesture are associated with the onset of referential communication, and this may have a neural basis in the left hemisphere. This association was not due to general maturation or to temporarily increased activation in the left hemisphere due to vocalizations that accompany pointing. It is possible that both language and gesture are both left-lateralized originally. The lack of any right-hand bias in infants with lower language abilities, however, suggests that a reorganization occurs at the onset of referential communication, such that pointing production becomes more lateralized as language develops. This change possibly develops through infant–caregiver interactions. As the study also found a relationship between productive vocabulary and pointing frequency, it also provides evidence for modality general factors in producing referential acts.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Appendix S1. Intercoder reliability and additional analysis.